

ACTS of Education

Robert Bauer, Richard Krawczyk
NASA Glenn Research Center
21000 Brookpark Road, MS 54-6
Cleveland, Ohio 44135 USA

PH: 216-433-3431; Fax: 216-433-6371; Email: Robert.Bauer@grc.nasa.gov

Frank Gargione
Satellite Systems Consultant
239 Glenn Avenue
Lawrenceville, NJ 08648
Tel: 609-883-4778; Fax: 609-883-0791

Hans Kruse
Ohio University
Stocker Center 333
Athens, Ohio 45701-2979
PH: 740-593-1566; Fax: 740-593-0007; Email: Hkruse@ohiou.edu

1.0 Abstract

Now in its ninth year of operations, the Advanced Communications Technology Satellite (ACTS) program has continued, although since May 2000 in a new operations arrangement involving a university based consortium, the Ohio Consortium for Advanced Communications Technology (OCACT). While NASA has concluded its experimental intentions of ACTS, the spacecraft's ongoing viability has permitted its further operations to provide educational opportunities to engineering and communications students interested in satellite operations, as well as a Ka-band test bed for commercial interests in utilizing Ka-band space communications. The consortium has reached its first year of operations. This generous opportunity by NASA has already resulted in unique educational opportunities for students in obtaining "hands-on" experience, such as, in satellite attitude control. An update is presented on the spacecraft and consortium operations.

2.0 New Operations Management

The ACTS spacecraft has been likened to the Energizer® bunny used to advertise the batteries' long life – they keep "going and going"! From its initial 2-year program that was extended to 4 years, then 5, and then 6, ACTS is approaching its 9th year anniversary. Even though the spacecraft exceeds 3 degrees of orbital inclination and is virtually out of onboard fuel, the payload continues to operate on primary systems.

Instead of shutting down the spacecraft in September 2000 as originally planned, NASA offered the management of the spacecraft's communications payload to an organization willing to form a university-based consortium that could use the system for education and learning initiatives. Such a consortium (OCACT) was developed by Ohio University (OU) located in Athens, Ohio, and this arrangement has been in place since May 2001 [1]. The consortium is responsible for providing the full cost of maintaining operations of the spacecraft through a reimbursable agreement with NASA. In return, the consortium has full utilization of the payload to support activities by its members and access to the spacecraft and

ground systems as an academic tool in the teaching of students. Consortium membership is open to universities as well as other government or commercial entities that desire to use the Ka-band testbed for experimental type activities [2].

It was realized that most consortium members had limited financial resources to support the consortium. As a result, the viability of the consortium rests on the contribution from a small number of commercial member organizations that perceive a large value in the use of ACTS in their business plans. The consortium's reliance on the financial contributions of one or two members makes OCACT vulnerable to a downturn in their fortunes. Due to the combined effect of failures of individual business plans and the recession in 2001, the financial viability of the consortium has been in jeopardy on several occasions, and the consortium has undergone almost continuous periods of refocusing and restructuring. At the time this paper was written, a month-to-month financial plan was in development to continue consortium operations. With the continued operations of ACTS and delay in deployment of any commercial Ka-band service, interest is again increasing in using ACTS as a testbed for the evolving next generation satellite services.

3.0 Consortium Activities in Telemetry Access

Early in the transition of ACTS to consortium control, two operational mandates had to be addressed. First, while the existing ground stations at the NASA Glenn Research Center in Cleveland, Ohio and Lockheed Martin in Newtown, Pennsylvania continue to execute all commanding, the contractor staffing at both locations has been reduced to a bare minimum to reduce the financial requirements for continued operations. At the same time, the consortium has been provided the opportunity to learn about the operation of the spacecraft and become involved in the daily operations decisions with NASA providing an oversight role.

Second, those consortium members involved in education required access to spacecraft telemetry to incorporate into their teaching tasks. To address the educators' needs, two layers of remote access capability were added to the existing control facilities. The consortium established a third operations center on campus at Ohio University in Athens, Ohio. While serving as a library of ACTS documentation so that payload configurations and other operational plans can be developed, the center also is equipped with several phone lines, facsimile capability, and several Internet-connected personal computers (PCs). Physical access to the center is restricted to authorized personnel to safeguard proprietary documents. The operations center also requires access to up-to-date status information about the spacecraft. The telemetry database system (Telemetry Archival and Retrieval System, TARS) used for ACTS is stored on optical disks, making accidental or malicious data erasure impossible. Fortunately, even though the database was designed to operate over a local area network, it uses the TCP/IP protocol set. Therefore, an Internet link between the consortium's operations center at OU and the database server at the Glenn Research Center was established. The server is protected by a firewall against unauthorized connection attempts. This configuration allows near-real time access to the spacecraft telemetry, as well as access to archived telemetry from the entire mission life. Consortium staff routinely use this database access to provide decision support to the operations staff at the Cleveland and Pennsylvania centers. To facilitate the use of this database access for teaching and research, remote login to some of the PCs in the consortium operations center has been established using another layer of network security. This permits students and faculty access to the telemetry data without necessarily permitting these users physical access to the operations center.

The Air Force Research Lab (AFRL), Rome, New York, called upon Ohio University, the lead member of OCACT, NASA Glenn Research Center, and support contractors at Lockheed Martin shortly after the planes hit the towers of the World Trade Center on September 11 to potentially support an emergency communication link. AFRL planned to use its Ka-band mobile satellite communications (SATCOM) terminal developed by its in-house engineers and tested over ACTS. Ohio University professors and students worked satellite technical issues and coordinated the activities of NASA and Lockheed engineers to establish and maintain the connectivity with ACTS. The entire team worked together throughout the evening of the 11th to get the entire satellite link and networking issues resolved and stood by throughout the next three days. Although an actual deployment was not required on September 11th, the team ensured that the technology was ready to meet the challenge [3].

4.0 Consortium Activities in Attitude Control

Typical communication satellites with large area coverage do not need active yaw control, since the normal yaw variation obtained from controlling roll does not affect satellite reception by the ground equipment. In the case of ACTS, the coverage is formed from very narrow (0.3 degree) spot beams, and the typical yaw variation, which can easily exceed one degree, can cause the loss of signal reception, especially for ground stations located at the edge of coverage on the West Coast, and much worse performance for remote locations like Hawaii, even though served by the steerable antenna whose beam width is 0.75 degrees for uplinking and 1 degree for downlinking. Since this type of performance would severely impact the usefulness of the ACTS spot beams a means had to be devised to provide active yaw control. The solution implemented uses two sun sensors mounted on the East and West faces of the spacecraft to provide a baseline reference during the two periods of the orbit when the sun is visible, and an estimator otherwise. The estimator is designed to propagate yaw attitude outside the sun sensing windows based on the disturbance torques estimated during the sun sensing windows, and to use the direct sun sensor outputs when they are valid. This system has historically (since late-1993) provided a pointing accuracy of less than 0.25 degree during normal operation. Occasionally, the yaw error exceeded 0.25 degree as observed by the sun sensor outputs during unusual geomagnetic activity, or if there was a reversal of polarity of the magnetic field during solar storms. When the spacecraft started to operate in the inclined orbit mode in 1998, the momentum wheel pivot could be programmed to control roll without disturbing the estimator operation, and good yaw control could be maintained. This changed, however, when inclination exceeded the pivot's control range of 2 degrees. Now the roll torquers are augmenting the pivot causing the estimator to perform poorly. Operations have reverted to the typical mode, with fixed coupling between the roll and yaw torquers. The resultant yaw error restricts operation to only part of the orbit period for stations at the edge of coverage, a situation that is not desirable, but acceptable under experimental conditions. In order to increase the usefulness of the satellite by decreasing the amount of yaw-induced signal fade, techniques are being investigated for measuring yaw using ground signal measurements, and then providing periodic uploads to the estimator to enable it to maintain the yaw error within acceptable ranges.

As was the original intent in transferring ACTS operations to a university, faculty and students at Ohio University (OU) have been increasing their understanding of ACTS operations and subsystems over the past year. With ACTS now greater than 3 degrees inclined, it is well beyond the orbital inclination it was designed for. Therefore, maintaining

or improving attitude control stability is a major factor in keeping the spacecraft's narrow spot beams pointed adequately to provide Ka-band links for consortium members. The most difficult aspect of spacecraft attitude to control is yaw, which also effects pitch and roll. Because of the spacecraft's "large" inclination, the on-board yaw estimator algorithm is no longer effective. OU developed a concept, and then, software for a ground-based estimator that can be periodically uploaded to the spacecraft attitude processor. A real-time demonstration of this concept was performed during an all-day test in April 2002 to verify the feasibility for significantly improving yaw error. This telemetry and command processing test involved telephone data lines and the Internet, linking students and faculty at OU in Athens with operations personnel at GRC's ACTS control station and the Lockheed Martin ACTS Operations Center in Newtown. While it is expected that additional tests will be developed and run to work out implementation issues, these activities provide a unique opportunity for students to get hands-on involvement in controlling a geosynchronous communications satellite.

5.0 Conclusion

Students at Ohio University have begun to use ACTS in their classroom and research work, in both communications and spacecraft control classes. Ohio University has filed a request for an experimental license with the FCC to allow the deployment and operation of consortium-controlled ground stations. Although usage for educational purposes has been the primary goal in keeping ACTS active, several consortium members from industry and government are actively using ACTS in the development of Ka-band hardware and satellite-based communications networks. ACTS is expected to remain useful for communications experiments for 1-2 years and as a teaching tool for up to 5 years. While uncertain if such a consortium could be developed, NASA's generous offer providing the spacecraft for academic usage has resulted in the extension of a unique spacecraft providing an exclusive laboratory for students and faculty of the OCACT.

6.0 References

- [1] R.Bauer, R Krawczyk, D. Irwin, H. Kruse, "Extending Acts Operations Through A University-Based Consortium," Proceedings of the 7th Ka-band Utilization Conference, Genoa, Italy, September 2001.
- [2] <http://www.csm.ohiou.edu/ocact/>
- [3] "Satellite Communications for Disaster Recovery," AFRL Technology Horizons, vol. 3 no. 2, June 2002, pps. 25-26.